THE DESIGN AND CONSTRUCTION

OF

AN UNDERSNOW CAMP

ON THE

GREENLAND ICE CAP

Corps of Engineers Project Number 13.2

1957

Report 1

March 1959

U. S. Army Polar Research and Development Center

Ft. Belvoir, Virginia

PREFACE

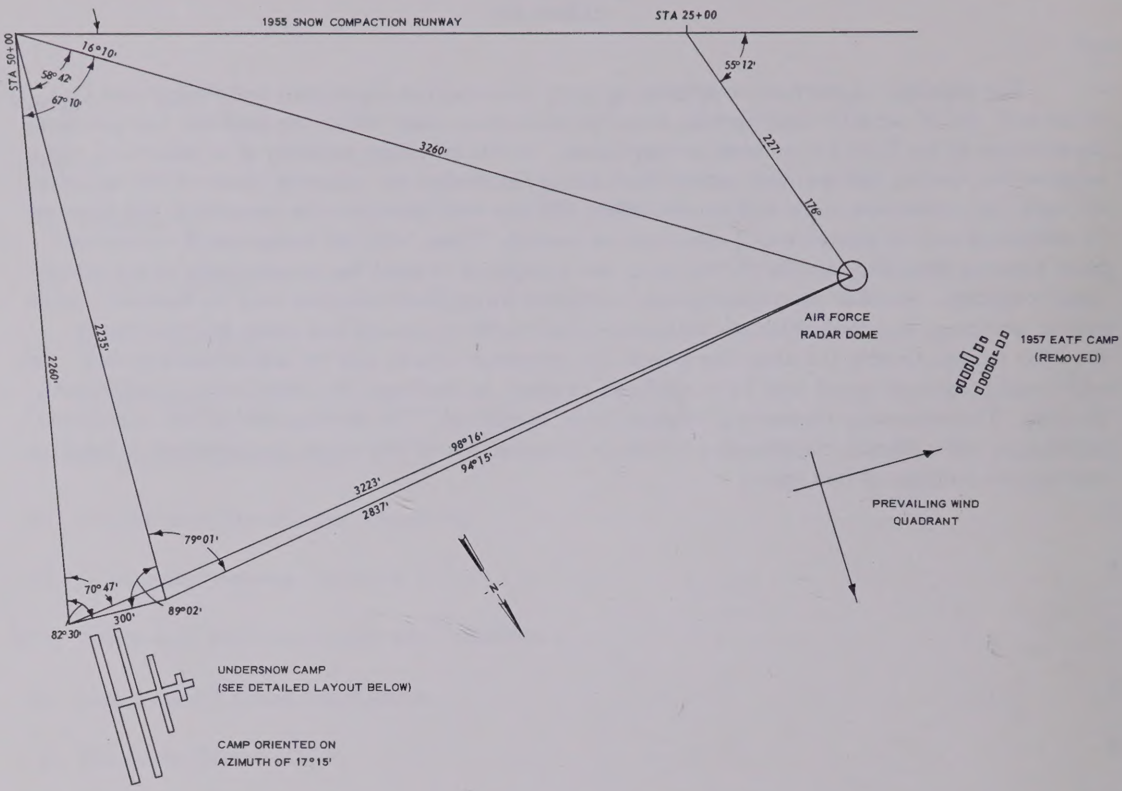
The work described in this report was conducted by personnel of the U. S. Army Engineer Arctic Task Force as a troop construction project for evaluation and test purposes, in addition to their operational support activity of constructing a year-round undersnow camp for future occupancy. The design and planning for this project were accomplished under the direction and supervision of the operations officer during the winter season (1956-1957), prior to commencement of the summer field work. Previous experience in this type of construction was virtually nonexistent. The corrugated steel tubes used by the U. S. Air Force for ice-cap installations were found to be impractical for the use here intended because of their extensive design, volume of materials involved, specialized labor required, and the resulting high costs.

Certain information obtained during the previous year's research—on the bearing capacities of snow, deformation of snow under loads of accumulated overburden, and the use of a specially designed snow miller for excavating necessary trenches—led to conclusions that an undersnow camp could be constructed at reasonable cost with troop labor and standard materials. The processes required to accomplish this operation were untried and planning factors utilized at the beginning of the project had to be revised as the work progressed. Designs of some aspects of the projects were changed as new information developed. More than one method of design or construction was employed wherever possible, consistent with available materials and the operational requirement of providing a usable shelter. This report covers the project as completed without dwelling overlong on processes of necessary changes.

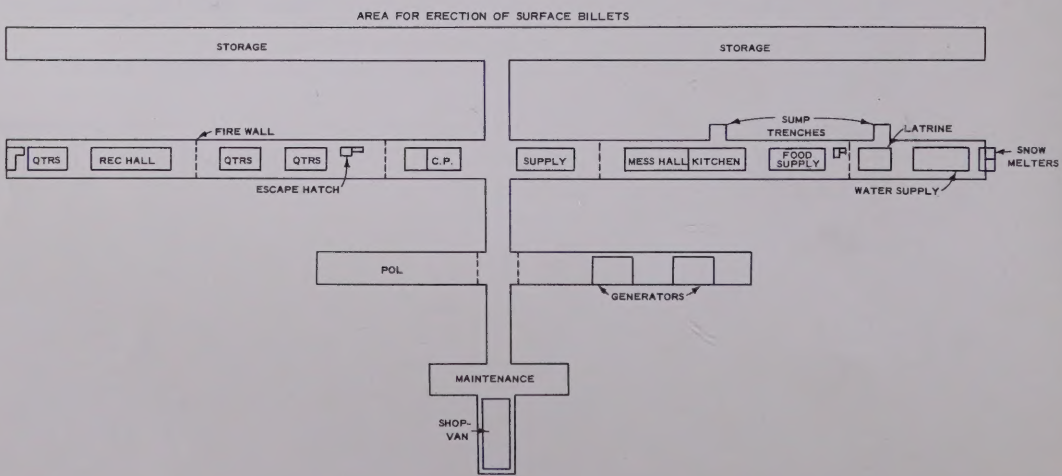
CONTENTS

SUMMARY

The principal objectives of developing troop construction experience and design data for future use, and of actually constructing a usable subsurface camp within the realistic and practical capabilities of the Task Force were accomplished. An initial target capacity of a year-round camp suitable for housing 150 men was established during the design and planning phase of the operation. As built, the undersnow camp will accommodate 100 men with provision for supporting and housing 50 additional men in above-snow Jamesways as needed. Thus, with the exception of necessary troop housing (sleeping facilities), the camp was completed to meet the requirements of the initial target capacity. Specific accomplishments completed during this operation were as follows: excavation, covering, and completion of installations within the personnel and camp utilities trench; the POL storage trench; the shop-van trench; the generator trench; and the maintenance trench. One additional personnel trench was excavated and covered, in readiness for installation of additional housing. The necessary connecting trenches were completed. The development of the operational techniques and methods recommended for use in construction of this nature is described in detail in appropriate portions of this report.



Location



Layout

Figure 1. Camp Fist Clench.

I. INTRODUCTION

1. Project 13.2, *Design and Construction of an Undersnow Camp*, was initially staged from Camp TUTO, Greenland, during the period 15 April through 8 May 1957. Project personnel arrived at the construction site 13 May 1957. Actual construction commenced 10 June and was completed 24 August 1957. During this period one officer and 27 men were assigned to the project. In addition, 15 men were engaged during about 50 per cent of the time on an as-needed basis. During the period 13 May through 10 June 1957 project personnel assisted in opening and enlarging the old above-surface camp in order to support the other Research and Development work to be carried on at Camp Fist Clench. Also during this period the undersnow camp site (see Fig. 1) was surveyed and marked, and some work was accomplished on prefabricating overhead truss members to be used in the undersnow construction. Throughout the season all roof truss material was cut and drilled at Camp TUTO prior to shipment to Camp Fist Clench for assembly. All materials and supply items except the Peter snow miller, the snowplow utilized in this project, were standard military items.

II. TRENCH EXCAVATION

2. It was decided in the early stages of planning to dig all trenches with the Peter snow miller. This is a track-mounted rotary snowplow manufactured by Konrad Peter, A. G., of Liestal, Switzerland. The model used was a gasoline electric machine, powered by twin Ford industrial engines which drive connecting generators. The plow is capable of cutting a trench 8 ft wide, to a maximum depth of 5 ft at the rate of 2 cu yd per min. This machine was satisfactory throughout the operation. Minor breakdowns, maintenance, and servicing did not cause any important delays or problems on the project. There were no major breakdowns. Fuel consumption during operation was found to be approximately 6 gal per hr. The tank capacity of 125 gal permitted servicing and operational maintenance to be accomplished without too frequent interruptions for service stops. The plow was operated a total of 153 hr on the project, or an average of 15.3 hr per week.

Prior to the actual cutting of the trenches the site was surveyed and fixed on the location map. Trenches were staked out with bamboo poles for easy visibility by the Peter plow operator. Stakes placed at intervals of 50 ft with 4 ft showing above surface were found to be satisfactory. Twine stretched between stakes proved unsatisfactory because it was too easily broken, and it was found unnecessary.

The first trench excavated was the personnel and camp utilities trench. This trench is 600 ft long, 20 ft wide, and 8 ft deep. It was excavated in increments 100 ft in length, and the erection of trusses and roofing was commenced immediately to prevent snowdrifting into and refilling the trenches in case of bad weather. By cutting two 8-ft paths and one 4-ft path, all 5 ft deep, and repeating this process on the ensuing lower level, the snowplow was capable of cutting 100 ft of trench in about three hours (see Fig. 2). This procedure was followed throughout the excavation of the first trench. It was necessary to cut a ramp for the snowplow each time a 100-ft section was excavated, but this did not create any problems or cause delays. It became apparent as the work progressed that time was saved by having a minimum of the uncovered trench open at one time to prevent snowdrifting and the subsequent necessity of replowing the trenches. The specifications for the second trench required a 16-ft width and a 10-ft depth to house the generators, and for POL storage area. An initial path was cut 24 ft wide and 2 ft deep before starting the 16-ft-wide excavation (see Fig. 3). This provided a 4-ft shoulder on each side of the trench. It was found that the more stable, consolidated snow at a depth of 2 ft provided a more suitable bearing surface for the overhead truss supports; also, it was easier to control the deposit of snow blown out of the trench during further cutting by the Peter plow. During excavation of the first trench it had been found that either too much or too

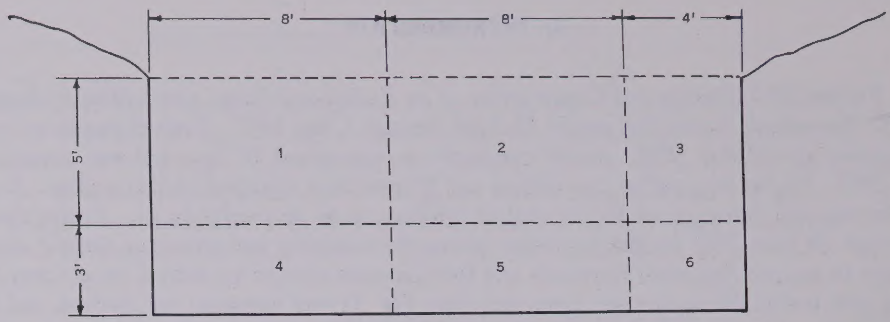


Figure 2. Excavation plan for personnel and utilities trench.

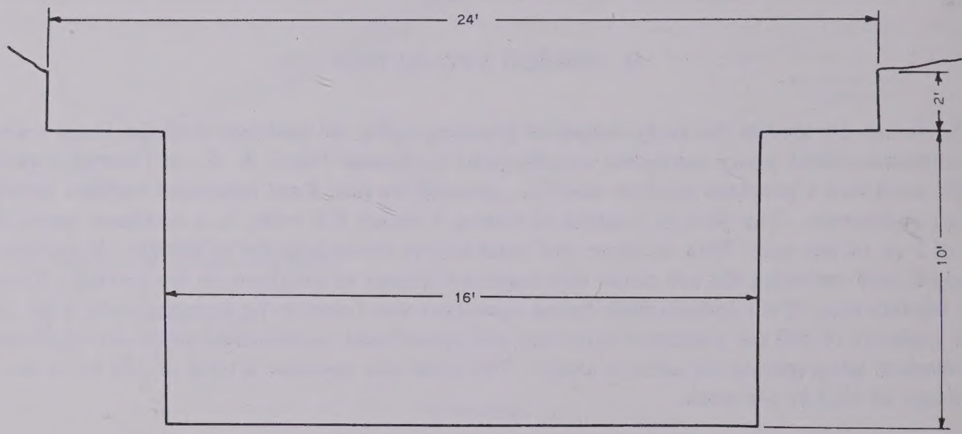


Figure 3. Excavation plan for POL storage and generators trench.

little snow was deposited near the edge of the trench where it was needed for backfilling during roof construction. Cutting of the shoulders facilitated better control of roof footings; therefore this procedure was used on all remaining trenches. An arbitrary bearing capacity of 10 psi was established for the roof footings. The 2-ft excavated shoulders provided satisfactory bearing surfaces for the load of 10 psi with negligible settling observed. A third reason for precutting shoulders was to avoid the effects of surface melt and thaw. Roof foundations were thus supported by snow which was insulated by the surrounding snow.

One additional operation in completing the trenches was necessary in order to provide connecting corridors between trenches. Over 240 ft of these corridors were completed, connecting the personnel and utilities trenches, the POL and generator trench, and the maintenance trench. The connecting corridors were at right angles to the trenches named. In addition, two 30-ft trenches were built to house the sewer pipes and outlets from the latrine and kitchen. (See as-built drawings on file at U. S. Army Polar Research and Development Center for all dimensions and trench locations.)

III. ROOF FOUNDATIONS

3. The erection of trusses and placement of covering over trenches were commenced immediately upon completion of excavation of each 100-ft section. Truss foundations initially consisted of

3- by 12-in. continuous runners, placed along the shoulders of the trench, to which the trusses were subsequently toenailed. Care had to be taken to obtain proper spacing of the runners with respect to width and elevation (see Fig. 4). The difficulties experienced in obtaining foundation alignment during the cutting and covering of the first trench were lessened during the remainder of the project by the technique of cutting shoulders described earlier.

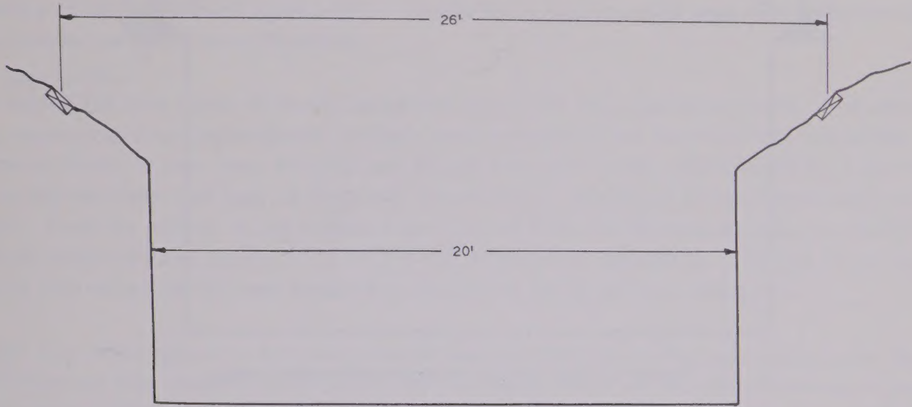


Figure 4. Roof foundations.

The 3- by 12-in. runners were utilized for only 300 ft of the first trench. It became necessary to utilize the available 2- by 12-in. stock for all remaining runners on the first trench. However, 2-by-12's were satisfactory and were much easier to handle and align. Field calculations indicated that the live loads imposed less than allowable fiber stresses. (See calculations in Appendix A.)

From the experience gained in placing the roof foundation on the first trench it was felt that the continuous runners were not required and another design was tried as an experiment. Field observations and load calculations indicated that 2-ft sections of the 3- by 12-in. runners placed on 4-ft centers would support the load requirements (see Fig. 5). This experiment was tried in an effort to determine if the use of sectionalized foundations was a more desirable method of construction. For this project it is concluded that the advantage of greater ease in handling of the sections was lost because of the greater installation time required.

Runners were modified to facilitate the erection of corrugated steel-arch trench covers, and the flat-type trusses. Three variations were used. Two types consisted of 6- by 6-in. continuous runners with 3- by 12- by 12-in. footers placed on 4-ft centers (see Figs. 6 and 7). The layout shown in Figure 7 appeared to be the most successful. The runners for flat trusses over the POL trench consisted of 2- by 12-in. runners without horizontal support (see Fig. 8).

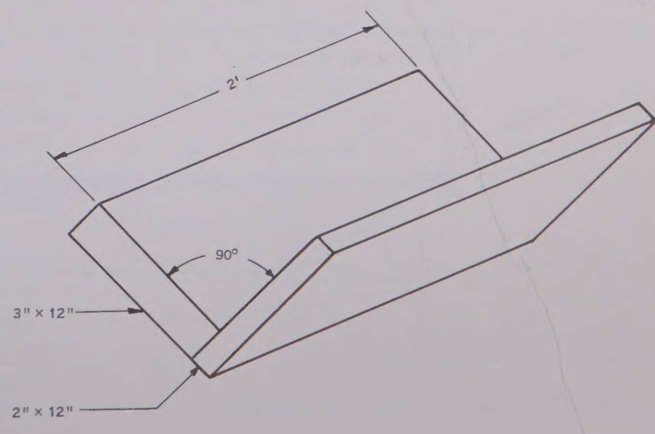


Figure 5. Design of experimental roof foundation sections.

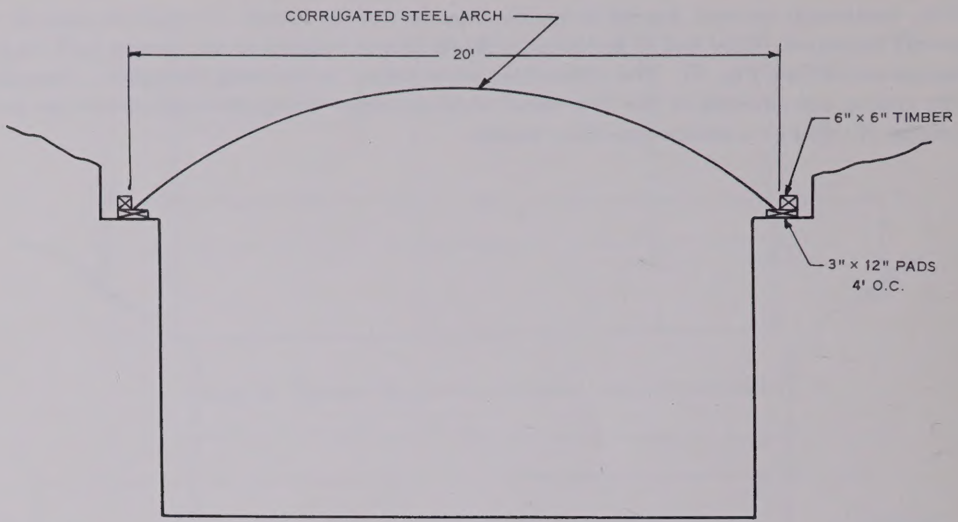


Figure 6. One type of arched trench-cover layout.

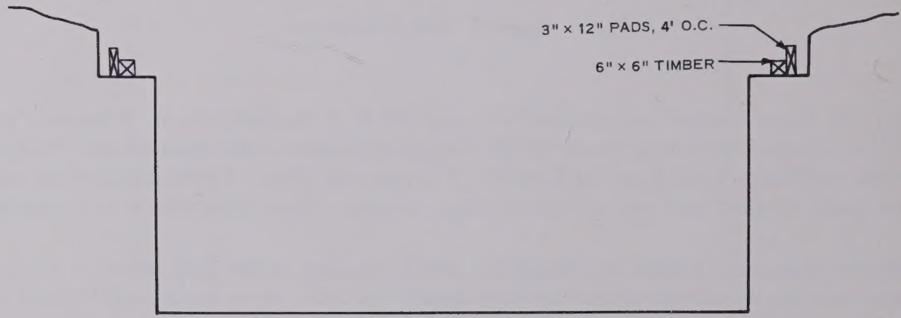


Figure 7. Most satisfactory arched trench-cover layout.

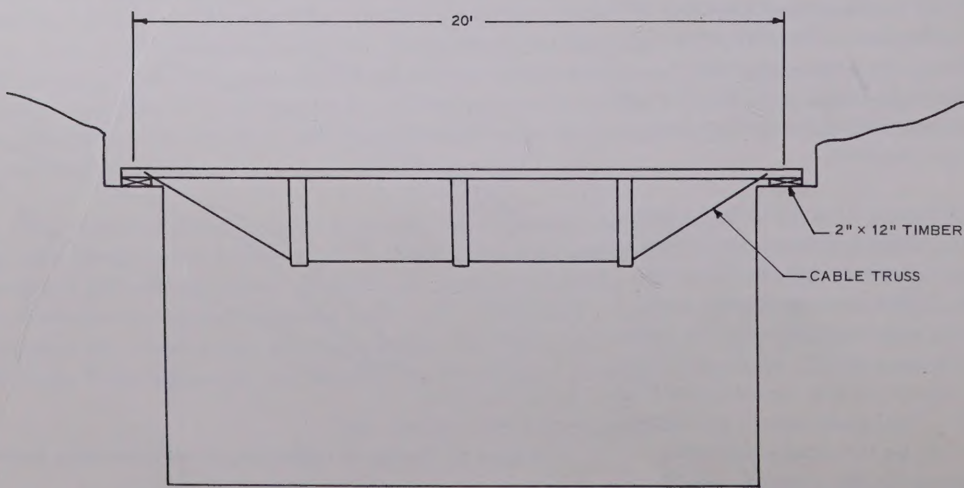


Figure 8. Layout of flat truss over POL trench.

IV. TRUSS DESIGN

4. Two general types of timber trusses were used, the overhead truss and the underslung cable truss. Of the overhead trusses, four subtypes were incorporated in the final construction, all of which were of common dimensions so that they could be used interchangeably. A useful result derived from the necessity of using different types will be the ability to observe each type of truss under stress and draw conclusions as to the most desirable.

Three of the four types of trusses used had 4-in. split ring connector joints. The advantage of split ring connectors over conventional, bolted joints is apparent but their use was impossible in the fourth type of truss. In this case 4-by-4's and 2-by-6 knee braces were substituted for 3-by-12's and 4-by-6's in the top chord and legs of the truss, respectively. Therefore 1/2-in. bolts were used without connectors. Upon the arrival of the needed 3-by-12's and 4-by-6's the original plan was followed. On several later occasions the supply of 3-by-12's was temporarily exhausted. The use of two each 2-by-12's or two each 4-by-6's was resorted to for the top chord in these instances.

The only other type of wood truss utilized was the flat-type cable truss placed over the POL trench. This truss was designed particularly for camouflage tests and for the advantage of least amount of material used per truss. The truss weighs about 25% less per unit than the overhead variety. The principal disadvantage of this type of truss is the lack of head room it affords.

In addition to trusses, the corrugated steel arch without trusses was utilized. It is evident that a more economical and/or stronger roof system could be designed using commercially available trusses. The corrugated steel was used because it was readily available as surplus material at TUTO. Two weights of steel were used, 4 gage and 8 gage. The 8-gage steel constitutes the roof of the 16-ft-wide generator trench while the 4-gage steel spans the 20-ft-wide maintenance and shop-van trenches. Both arches have a radius of 15 ft.

Through experience gained on the generator trench it was found that the corrugated steel was too heavy to remain adequately supported on short 1-ft pads. Even relatively small, concentrated loads caused the pad to become separated from the runner, weakening the entire foundation (see Fig. 9). This condition was alleviated to some extent by carefully packing snow beneath the runners.

V. STEEL-ARCH ROOF ERECTION

5. The corrugated steel arches were in sections which had to be fabricated adjacent to the job site, with a four-man crew and the tractor-mounted crane. One section was picked up by the tractor-mounted crane and placed upon another section until bolts were fastened. Steel sections over the maintenance and shop trenches were assembled using 3/8-in. bolts, since the supply of 1/2-in. bolts was depleted. The 3/8-in. size bolts caused a weakening of the assembled arch and created undue additional work, but were used only as a last resort rather than stop the project. The corrugated steel arches were erected in 8-ft increments by the tractor-mounted crane. The crew of four men, plus crane operator, stabilized and guided the arch into place, utilizing rope and guy lines.

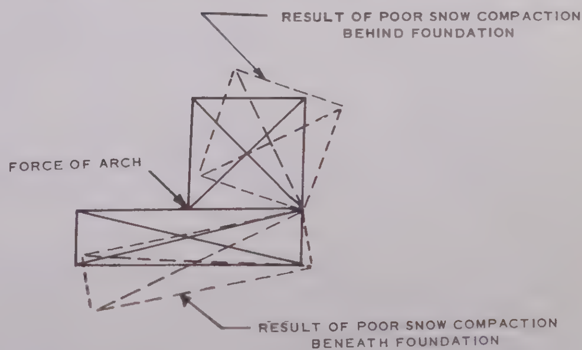


Figure 9. Separation of pad and runner under load.

VI. TIMBER ROOF ERECTION AND SHEATHING

6. Following the laying of the foundations (runners), trusses were erected and the sheathing was immediately put in place, in a continuous, concurrent operation. The trusses averaged 330 lb each. Throughout approximately half the operation, placement of the trusses was accomplished by hand from a scaffold which was built on top of a 10-ton sled. Trusses were hand-carried across the trench, using the scaffold as a bridge. As work progressed, the sled was moved along in the trench by tractor. Later, a tractor-mounted crane was used for some of the wooden trusses and all of the corrugated steel arches. All flat, cable-type trusses, being lighter and more easily handled, were placed by hand.

Several types of sheathing were used to cover the timber truss roof supports. Hard and soft wood sheathing and plywood of several weights were used. Throughout the construction of the timber roofs, polyethylene film was used for purposes of waterproofing. Because of excess deflection and cost, the plywood proved unsatisfactory as a covering material. Standard 1- by 6-in. sheathing lumber was easiest to place. The strongest, cheapest, and generally most satisfactory was the 1- to 2-in. random width and random length "dunnage" lumber. This dunnage lumber was available in large quantities at Thule Air Base port. While difficult to nail, being generally oak wood, it has an average thickness of 1-1/2 in. which is satisfactory for roof sheathing.

One-inch Fiberglas insulation material was initially used to cover the first trench as a temporary shield against wind-blown snow. The Fiberglas was easily torn by light winds, and was used only as an expedient prior to arrival of roofing materials and the polyethylene film at the job site.

Polyethylene film was found to be very successful as the roof finish. It was easily installed and could withstand a limited amount of stress by itself without failure. This property proved extremely valuable near the close of the season. To stretch the supply of dunnage and wood sheathing material, the last 250 ft of roof was sheathed by leaving 3-in. gaps between each 6-in. board. After laying, the polyethylene was covered with a few inches of Peter snow to prevent flapping and possible tearing. Generally, however, the polyethylene was secured with lathing strips.

The construction of the several intersections between trenches presented certain problems. Intersections between the 8-ft-wide corridors and the main trenches were constructed by spanning the entranceways of the corridors. This was done by reinforcing the main roof runners with 3- by 12-in. or 2- by 12-in., 14-ft-long members centered over the corridor, and adding posts at the corners for additional support. The bases of the posts were erected directly on the snow floor, without load-distributing footings, in order to permit equal settlement between the intersection structure and adjacent roof structures.

Spanning the intersection between the steel-roofed trench and the corridors presented a slightly different problem. Runners had to be laid flat under the edges of the corrugated steel, and the steel roof presented a much heavier initial dead load. In addition to the runner, a 12-ft, 6- by 8-in. beam was placed across the 8-ft span. At first it was thought that supporting posts would be necessary beneath the beams, but after they had been installed for about two months only minor settlement had occurred. Intentionally designing for settlement is, in fact, often very desirable in temporary, snow-loaded structures, for it reduces the pressures that build up rapidly as the snow accumulates and consolidates. Consequently, posts were not used except where absolutely necessary to maintain minimum, or at least uniform, settlements between structures. This principle was used throughout the design of the entire camp, as may be seen in the relatively light or small roof-supporting runners and beam supports. The widest and most difficult intersection was that between the 20-ft-wide maintenance trench and the 20-ft-wide shop-van trench. A structural steel beam (18 I 55), 26 ft in length, was used to span the entrance to the 20-ft shop-van trench. Each end of the beam was seated on two each 2- by 12- by 24-in. footers, with expectation of some settlement, as discussed above. The steel beam was set so that the

lower edge of the corrugated steel arch rested on its bottom flange. This expeditious method provided both vertical support, from the flange, and lateral thrust support, from the web of the beam. The corrugated steel-arch sections were bolted to the web of the steel beam. The ends of the beam itself were secured to the steel-arch sections of the opposite (maintenance) trench by welded steel plates.

VII. SNOW-ROOFED ACCESS CORRIDORS

7. The access corridor roofs were constructed using the relatively new snow-bridge technique developed and tested by the USASIPRE *Snow Structures* project. The open, 8-ft-wide trenches were first covered with thin sheets of corrugated aluminum-arch sections (see Fig. 10). The arch sections rest on special portable runners which are temporarily staked to the snow walls of the trench. After the forms were placed, Peter snow was blown back on top of the arch sections to a depth of 2 ft. This snow was allowed to set up for 24 hours, by which time its hardness was sufficient for removal of the steel forms. Forms were easily removed from inside the completed tunnel.

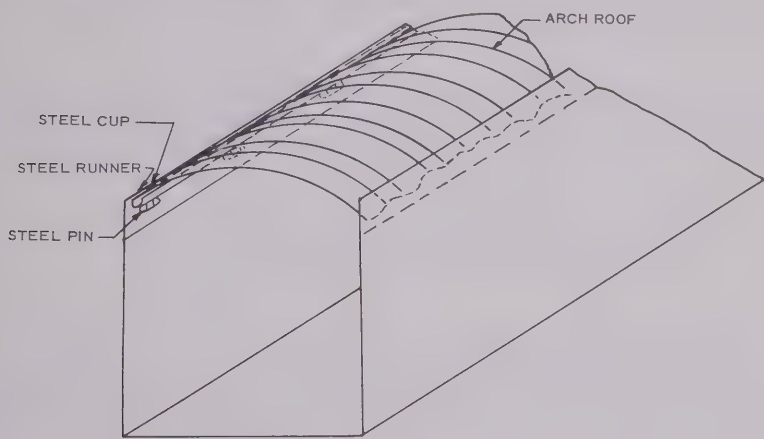


Figure 10. Layout of access corridor roofs for snow-bridge cover.

The primary advantage of using the snow-arch roof is that the forms may be removed and used repeatedly. This technique has not been tested on trenches wider than 8 ft, but will be the objective of further testing during the 1958 program. To construct snow-arch roofs over wider gaps will also require that trenches be deeper, in order to construct thicker, stronger snow arches. Thus, the snow miller must be equipped with higher chutes and/or more powerful blowing action. A more complete discussion of snow-arch construction may be found in reports published by USASIPRE, CE Project 13, *Snow Structures*.

VIII. ERECTION OF BUILDINGS INSIDE THE TRENCHES

8. Most of the shelters used in the trenches were Jamesways. The kitchen, latrine, and generator housing were of prefabricated, plywood-panel construction. The Jamesways had a width of 16 ft erectable to any length in 4-ft increments. To permit a 4-ft walkway along one side, and to facilitate erection of the buildings, each side of the trenches was undercut 1 ft, for a height of 4 to 5 ft from the floor (see Fig. 11). The portion enclosed in dotted lines was later removed by hand, using saws and small "go-devil" sleds. Foundations consisted of 4- by 4-in. piles driven about 1 ft into the snow on 8-ft centers. Piles were capped with 4- by 4-in. beams, at a height of 1.5 ft above the snow floor. The caps formed floor "boxes."

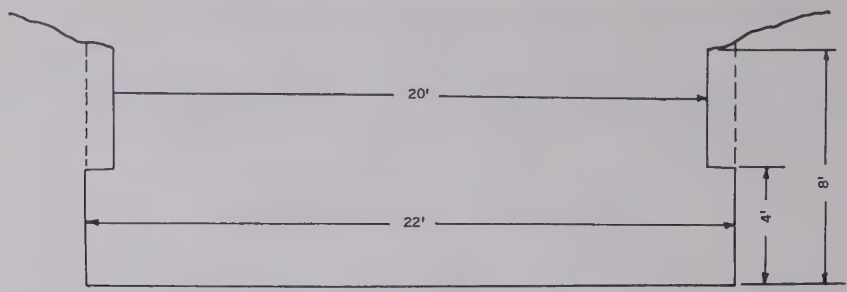


Figure 11. Undercutting of trench walls to provide space for walkway and shelters.

The 1.5-ft elevation above the snow floors formed a free air space beneath the floors to prevent conductive heat transfer with resulting melting and settlement. The use of artificial, rather than convective, circulation was considered in the planning, but was postponed until the performance could be observed and data collected on the imposed temperature regimes. Information will be obtained on heat transfer in snow structures in relation to surface conditions, internal heating, snow permeability, and the "cold sink" effect of surrounding snow.

To be complete, the trenches required the addition of wooden walkways. The majority of these will be completed in 1958. Even foot traffic caused the snow floor to become pulverized to a depth of 6-12 in., making walking difficult as well as tending to block the free air space under the structures.

IX. LATRINE AND KITCHEN INSTALLATION

9. The latrine and kitchen buildings were of prefabricated plywood panels. While neither the construction nor design was unique, the panels were specially designed for three particular objectives. First, the uniform panel size, 4 by 8 ft, conformed to the size of plywood sheets themselves, thus eliminating undue cutting or waste. Second, the 2- by 4-in. studding permitted space within the panels (between plywood faces) for 2-in. insulation and a 1- to 2-in. dead air space. Width of the air space varied because of irregularities in insulation batt thickness. Although the batts were cut from rolled insulation, definite efforts were made during fabrication to maintain the air seal between the insulation and the dead air space. Third, the use of the panel system itself permitted prefabrication at the TUTO base camp and speedy and easy erection at Site 2. Jamesways were not desirable for these structures because of their limited head clearance and wall curvature.

Shower stalls were erected 18 in. off the floor so that adequate fall could be obtained in the drainpipes between showers and toilets. The toilets comprise a central collecting point for all waste water from showers and washbasins, and are therefore the lowest utility in the latrine building.

Kitchen installation was no problem as far as drainage was concerned. The only difficulty is cramped quarters. Consideration must be given to increasing the size in 1958, if maximum occupancy of the camp is anticipated for an extended period.

X. ELECTRICAL SYSTEM

10. Power was supplied to all trenches in the camp. With the exception of the kitchen and the shop-van, which are 220-volt, 3-phase power, all fixtures are 110 volts, single phase. In wiring the

trenches, an effort was made to keep the phases as nearly balanced as possible.

The power plant consists of two diesel-operated generators, one of 100-kw and the other of 30-kw capacity. Power for the camp is supplied by the 100 kw with the 30 kw used as a stand-by in the event of an emergency. Either generator can be switched on or off the main circuit as desired. (Generators were placed 25 ft apart as a precaution against fire.) All main lines consisted of #6 wire; leads into the huts were #14; #10 was used in the maintenance trench. Lines were suspended from angles built of scrap lumber and nailed to the trusses or from poles bolted to the steel roof. In the small access trenches scrap lumber was driven into the walls and wiring attached to the free end. A breakdown of the amount of wire used is: 5000 ft of #6 wire, 350 ft of #10 wire, and 500 ft of #14 wire.

XI. WATER SUPPLY SYSTEM

11. Hot and cold running water was supplied to the latrine and the kitchen buildings. No other buildings in camp have running water, but facilities have been arranged so that occupants may hand-carry water cans to individual living quarters.

The source of water supply is two snow melters mounted on a platform at one end of the camp utilities trench. Except for the hoppers, the snow melters and platforms are completely enclosed. A small door at the back of the trench was provided for easy accessibility to and from the hoppers.

The snow melters were elevated approximately 9-1/2 ft above the trench floor to obtain gravity feed to the storage tanks. The platform support for the melters was erected on nine 6- by 6-in. timber piles and three 4- by 4-in. piles inserted 5 ft into the snow. Snow was packed around the piles, saturated with water, and allowed to freeze.

The pile foundations for the other concentrated heavy loads located in the shop-van and the generator building were constructed in a similar manner, except that the platforms were elevated only about 2 ft above the trench floor. A great amount of care was taken in constructing these pile foundations, and observations were made several times weekly to determine the rate of settling. Differential settling was a prime concern during these observations. The statistics of pile loads on the various structures, and a comparison of the results obtained in the 1956 pile tests conducted by SIPRE Project 33 are contained in Appendix A.

Water storage was provided by two 1100-gal storage tanks. These were mounted inside a Jamesway hut, on piles which passed through the floor and into the snow. Water lines were installed in a circulating system, with return lines for both hot and cold water to prevent freezing. Two 15-gpm pumps circulate cold and hot water, respectively. Drainage valves are located so that the entire system can be drained in case of a shutdown for any reason. The water pipes are insulated with standard asbestos insulation, and all lines are supported by overhead straps constructed from dunnage lumber.

XII. WASTE DISPOSAL SYSTEM

12. Disposal of waste water is through 8-in. steel pipes leading to closed sump pits in snow. The tops of these pits consist of 55-gal drums with both ends removed. The drums were sunk vertically into the snow, and water is allowed to seek its own level in the vertical shaft that is melted out (see Fig. 12). Two such arrangements were installed for the latrine and kitchen, respectively. Each was located 30 ft back into the snow from the side of the trench. Identical arrangements were used in both latrine and kitchen sumps. Horizontal accessways from the main trench back to sump locations were

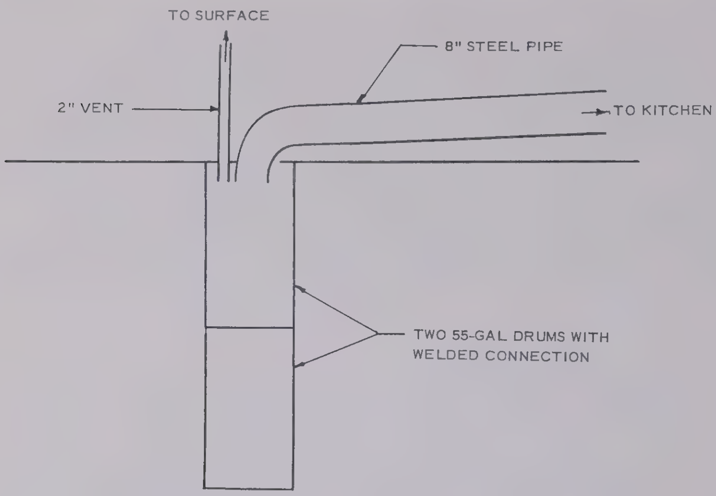


Figure 12. Waste disposal pit.

dug by the Peter plow and covered with the snow-arch system described earlier in the report. The resulting tunnels allow easy access to the pipes and sumps for future observation and measurements of the pit depth, and for maintenance. The sewer pipes were enclosed in wooden humidors supported on 4- by 4-in. piles. Four inches of Fiberglas insulation was placed around the sewer pipe inside the wooden trough. The square troughs were further packed with insulating material and covered with 1- by 6-in. lumber (see Fig. 13).

Main sewer lines were constructed of 8-in. steel pipe instead of the 4-in. cast iron pipe originally planned owing to the unavailability of the latter. A 3/4-in. hot-water line with valve and hose fitting was installed in conjunction with the sewer systems for flushing out lines in the event that normal flow is insufficient for self-cleansing action.

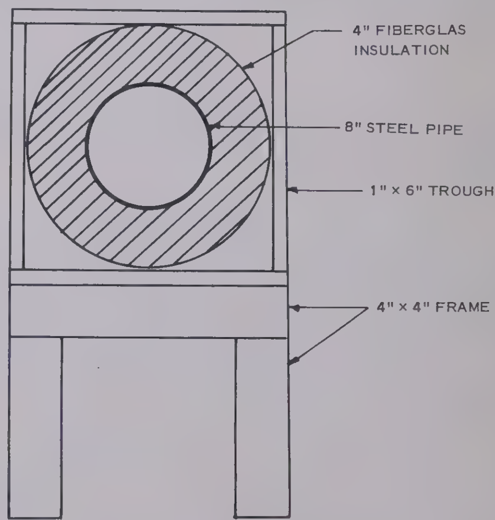


Figure 13. Section of sewer line.

XIII. HEATING AND VENTILATION

13. Heating of the huts is by 50,000-btu per hr, diesel-fuel space heaters, one per 16- by 32-ft Jamesway hut. In longer huts, the number of stoves is increased proportionately. At present, these stoves are temporarily fed from standard 5-gal fuel cans. Since that amount of fuel is consumed in approximately 10 hours, a more desirable system is necessary. During the construction season, special carburetor adaptors and fuel hoses were assembled, but not mounted, which will permit the use of fuel directly from 55-gal drums to be located in the trench outside the respective huts. A central fuel supply is planned for generators, snow melters, and water heaters. A more extensive central fuel system would be practical but is not planned in this installation.

Two methods of stove exhaust-pipe installation were used for comparison. In one, a horizontal exhaust pipe was installed 12-18 in. from the ceiling, from above the stove out to the end of the Jamesway, and thence vertically up through the trench roof. This system required two 90-deg elbows per stove. The second method was to run the pipe vertically up through the Jamesway roof, without any elbows. For best ventilation, the latter method proved to be the more satisfactory. Although the horizontal system radiated a slight extra amount of heat, the elbows tended to collect soot.

XIV. ESCAPE HATCHES

14. Three escape hatches were constructed in the 600-ft personnel trench. One is located on each end of the trench and one in the middle. These consisted of about a 45-deg ladder leading up to a 5-ft-square landing, from whence another ladder leads up to a trap door in the trench roof. The platform is about halfway between the floor and the roof, allowing ample room for handling emergency supplies, and medical and personal equipment. One special feature which was incorporated into the design of the escape hatches is that the lower end of the upper ladder rests on the platform without being secured. Thus, as inevitable settlement takes place in the roof, the ladder will be free to slide along the platform without stress.

APPENDIX A

In comparing pile loads of structures in the new camp with results obtained from Project 33, *Pile Test*, it can be seen that snow stresses in the new camp are considerably less than those obtained on the test piles. The conclusion drawn from pile test figures is that stresses up to 200 psi can be sustained without appreciable settlement or failure. All stresses in the new camp, however, are 90 psi or less. Another factor to be considered is the presence of side friction on piles in the new camp, something which was absent during the pile tests of Project 33. The exact stabilizing influence of side friction is unknown at this time, other than the fact that it is present and can be considered a safety factor of unknown magnitude in pile construction.

Pile loads on various structures in undersnow camp.

Snow melter.

Total DL + LL includes weight of platform, two snow melters, and weight of water when both snow melters are filled to capacity.

DL + LL = 34,600 lb

Piles: 9, each 6 in. by 8 in. by 14 ft, sunk 6 ft into snow
Total cross-sectional area = 387 in.^{2}

$$\text{Pressure in psi} = \frac{34{,}600}{387} = 89.5$$

30-kw generator.

Total DL + LL includes weight of platform and generator.

DL + LL = 16,600 lb

Piles: 24, each 6 in. by 8 in. by 7 ft, sunk 5 ft into snow
Total cross-sectional area = 1030 in.^{2}

$$\text{Pressure in psi} = \frac{16{,}600}{1030} = 16.1$$

100-kw generator.

Total DL + LL includes weight of platform and generator.

DL + LL = 18,000 lb

Piles: 24, each 6 in. by 8 in. by 7 ft, sunk 5 ft into snow
Total cross-sectional area = 1030 in.^{2}

$$\text{Pressure in psi} = \frac{18{,}000}{1030} = 17.5$$

Shop-van.

Total DL + LL includes weight of platform and fully equipped shop-van.

DL + LL = 48,400 lb

Piles: 35, each 6 in. by 8 in. by 7 ft, sunk 5 ft into snow
Total cross-sectional area = 1510 in.^{2}

$$\text{Pressure in psi} = \frac{48{,}400}{1510} = 32$$

Results of 1956 pile test.

Load, lb	Settlement, in.	Time, hr	psi
10-in. Pile with Bottom Plate - 10.75-in. Diameter			
9,320	15/16	21.5	102.5
12,760	1-3/16	47.75	140.5
17,920	2	92.75	197.5
23,080	1	48	254.0
28,240	4-5/16	237.75	311.0
3-in. Pile with 4-in.-Diameter Plate			
488	3/32	45	38.9
1,414	9/32	29.75	112.5
2,339	1-1/2	167.25	186.5
3,449	3/4	89.75*	275.0

* Pile still settling.

Date Due
